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DISTORTION COMPENSATION DEVICE
[Hizumi hoshoki]

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Specification /7*

1. Title of the Invention

DISTORTION COMPENSATION DEVICE

2. Claim

A distortion compensation device, wherein the distortion compensation device comprises an input-end hybrid (10) for receiving and splitting microwave signals (Sin) into two signals (S1, S2) with a 90° phase difference with respect to each other, and an output-end hybrid (20) for receiving two microwave signals being the output (S1c) of a phase shifter (11) providing a phase shift to one (S1) of the two signals split by the input-end hybrid (10) in order to maintain the 90° phase difference between both signals (S1, S2) and the output (2Sc+Sd) of a distortion generator (21) for simultaneously generating the sum of the main signal (S2c) at a given level of the non-linear amplified other signal (S2) split by the input-end hybrid (10) and a distortion signal (2d), performing a phase reversal, canceling out the main signal components (S1c, S2c) of the inputted microwaves, and only outputting the distortion signals component (Sd) from the output terminal (t3), wherein a control signal generator (30) for generating control signals C based on the level of the microwaves (Sc) synthesized with the same phase at the end terminal (t4) of the output-end hybrid (20), a variable phase shifter (11) for applying a phase shift to one (S1) of the two signals (S1, S2) split by the input-end hybrid (10) using the control signals C so the error

*Numbers in the margin indicate pagination in the foreign text.

ε from the correct 90° phase difference between the two signals (S1, S2) is zero, and a variable attenuator (12) for correction of the output level from the variable phase shifter (11) are disposed in the distortion compensation device, and wherein the variable phase shifter (11) and variable attenuator (12) are controlled independently by the control signals C generated by the control signal generator (30), the variable phase shifter applies a phase shift to the microwave signals (S1) outputted from the input-end hybrid (10) so the level of the microwave signals at the output terminal (t3) of the output-end hybrid (20) is fixed, and the variable attenuator (12) changes the output level of the variable phase shifter (11).

3. Detailed Description of the Invention

(Summary)

[01] The present invention relates to a distortion compensation device installed in front of a high-power microwave amplifier for /8 outputting microwave distortion signals to compensate for the distortion generated by the high-power microwave amplifier; the purpose of which is keep the output level of distortion signals from the distortion compensation device constant by operating the variable phase shifter so there is no variance from the correct 90° phase difference between the two signals from the split of the microwave input for distortion signal compensation; and comprising a distortion compensation device, wherein the distortion compensation device comprises an input-end hybrid for receiving and splitting microwave

signals into two signals with a 90° phase difference with respect to each other, and an output-end hybrid for receiving two microwave signals being the output of a phase shifter providing a phase shift to one of the two signals split by the input-end hybrid in order to maintain the 90° phase difference between both signals and the output of a distortion generator for simultaneously generating the sum of the main signal at a given level of the non-linear amplified other signal split by the input-end hybrid and a distortion signal, performing a phase reversal, canceling out the main signal components of the inputted microwaves, and only outputting the distortion signals component from the output terminal, wherein a control signal generator for generating control signals C based on the level of the microwaves synthesized with the same phase at the end terminal of the output-end hybrid, a variable phase shifter for applying a phase shift to one of the two signals split by the input-end hybrid using the control signals C so the error ε from the correct 90° phase difference between the two signals is zero, and a variable attenuator for correction of the output level from the variable phase shifter are disposed in the distortion compensation device, and wherein the variable phase shifter and variable attenuator are controlled independently by the control signals C generated by the control signal generator, the variable phase shifter applies a phase shift to the microwave signals outputted from the input-end hybrid so the level of the microwave signals at the output terminal of the output-

end hybrid is fixed, and the variable attenuator changes the output level of the variable phase shifter.

(Industrial Field of Application)

[02] The present invention relates to a distortion compensation device for microwaves installed in front of a high-power microwave amplifier to correct the amplitude distortion when modulated microwave signals undergo electric power amplification and, more specifically, to a distortion compensation device for microwaves in which received microwave signals are split into two signals [S1, S2] with a 90° phase difference with respect to each other by an input-end hybrid, a phase shifter applies the necessary phase shift to one of them [S1] to maintain the correct 90° phase difference, the other undergoes non-linear amplification by a microwave amplifier to generate distortion signals for compensation, the two microwave signals [S1, S2] with the correct 90° phase difference and no level difference are synthesized by a split-line output-end hybrid, and only the distortion signals generated by the non-linear amplitude microwave amplifier are outputted for linear distortion compensation in the high-power amplifier.

(Prior Art)

[03] In a microwave distortion compensation device of the prior art, as shown in the block diagram in FIG 4, modulated microwave signals [Sin] with a plurality of modulated carrier waves (1) are inputted to the input terminal [t1] on a split-line input-end hybrid [10A] with input terminal [t2] terminated by resistance [R1], the

signals are split into two microwave signals [S1, S2] (2) with amplitudes at output terminal [t3] and output terminal [t4] equal at about 1/2 and a phase difference of 90° with respect to each other, the one [S1] being adjusted by a phase shifter [11A] so the error ε from the correct 90° phase difference between the two split signals is zero and then outputted as output [S1c] (3), the other [S2] being inputted to a microwave amplifier [21A] to undergo non-linear amplification and generate microwave distortion signals [Sd] (4) at a given level, and be sent to the input terminals [t1, t2] of the split-line output-end hybrid [20A] as output signals (S2c+Sd) (5) which are the sum of the main signals [S2c] and the distortion signals [Sd].

[04] At the output-end hybrid [20A], the two outputs, output [S1c] and output [S2c+Sd], which have equal levels and the correct 90° phase difference, are inputted to the input terminals [t1, t2] and synthesized with the main microwave signal components [S1c, S2c] synthesized in reverse phase to cancel them out so only the distortion signal component [Sd] generated by the non-linear microwave amplifier [21A] is outputted as output signals [Sout] (6). The distortion signals, which are the output signals [Sout] (6) outputted from the output terminal [t3], are inputted to the high-power amplifier [100] so as to compensate for any distortions generated. One of the output terminals on the output-end hybrid [20A], end terminal [t4], is terminated by resistance [R2], and the two microwave signals [S1c, S2c] inputted to the input terminals [t1,

t2] are synthesized at the same phase so the maximum level occurs when the phase difference is at the correct 90° phase difference. When not at the correct 90° phase difference, the microwave signals [Sc] with a level reduction proportional to the phase error ε are outputted to the end terminal [t4].

(Problem Solved By the Invention) /9

[05] In distortion compensation devices of the prior art as described above, the two microwave signals [S1c, S2c] from the microwave signal input [Sin] split in two by the input-end hybrid [10A] undergo the necessary phase shift in the phase shifter [11A] so as to maintain a 90° phase shift between them. However, if the correct 90° phase shift is not maintained and there is a phase error ε at the input terminal [t1, t2] of the output-end hybrid [20A], the main signals [S1c, S2c] are not sufficiently canceled out at the output terminal [t3] on the output-end hybrid [20A], main signal components [S1c, S2c] are contained in the distortion signal output [Sout] from the output terminal [t3], the level of the distortion signal output [Sout] from the distortion compensation device changes, and the distortion compensation in the high-power microwave amplifier is inadequate.

[06] In order to prevent this, the phase shifter [11A] has to make adjustments so there is no phase error ε from the correct 90° phase difference between the two microwave signals [S1c, S2c] at the input terminals [t1, t2] on the output-end hybrid [20A]. In the

prior art, a spectrum analyzer measures the output signals corrected by the phase shifter [11A] at the output terminal [t3] of the output-end hybrid [20A] and changes the amount of shift by the phase shifter [11A] so that the level of the main microwave components [S1c, S2c] at output terminal [t3] is minimal. If necessary, another means adjusts the length of the conductive pattern in the microwave transmission line between the input-end hybrid [10A] and the output-end hybrid [20A].

[07] However, these means of adjusting the output from the phase shifter [11A] are complicated, time-consuming and expensive. In order to solve this problem, the present inventors provided a microwave distortion compensation device that automatically corrects a phase shifter [11A] also invented by the present inventors.

[08] While this microwave distortion compensation device that automatically corrects a phase shifter [11A] had no problem correcting the phase difference generated by the phase shifter [11A], the phase-shifting operation of the phase shifter [11A] caused a change in the output level of the phase shifter [11A]. As a result, the level of the microwave distortion signals [Sout] outputted from the output-end hybrid [20A] and distortion compensation device was changed, and the distortion compensation in the high-power microwave amplifier [100] was inadequate.

[09] The purpose of the present invention is to solve the problem of the level of the microwave distortion signal output [Sout] from the distortion compensation device being changed by the phase-

shifting operation of the phase shifter [11] and causing subsequent inadequate performance.

(Means of Solving the Problem)

[10] This problem is solved by the distortion compensation device of the present invention shown in FIG 1, in which a control signal generator [30] for generating control signals C based on the level of the microwaves synthesized with the same phase at the end terminal [t4] of the output-end hybrid [20], a variable phase shifter [11] for applying a phase shift to one of the two split signals [S1, S2] to maintain the correct 90° phase difference, and a variable attenuator [12] for correction of the output level from the variable phase shifter [11] are disposed in the distortion compensation device, and in which the variable phase shifter [11] and variable attenuator [12] are controlled independently by the control signals C generated by the control signal generator [30], the variable phase shifter applies a phase shift to microwave split signal [S1c] to maximize the microwave signal level [Sc] at the end terminal [t4] of the output-end hybrid [20], and the variable attenuator [12] changes the output level of the phase shifter [11].

[11] In the FIG 1 schematic showing the configuration of the distortion compensation device of the present invention, 10 denotes an input-end hybrid for receiving and splitting microwave signals [Sin] into two signals [S1, S2] with a 90° phase difference with respect to each other but the same output level, 11 denotes a variable phase shifter for applying a phase shift to one [S1] of the

two signals [S1, S2] split by the input-end hybrid [10] using the control signals C so the error ε from the correct 90° phase difference between the two signals [S1, S2] is zero, 12 denotes a variable attenuator for changing of the output level from the variable phase shifter [11] and outputting a microwave main signal [S1c] with a level equal to the level of the main signal [S2c] output from the distortion generator [21], 21 denotes a distortion generator for inputting the microwave split signal [S2] outputted from the input-end hybrid [10], performing non-linear amplification, generating a distortion signal [Sd], and outputting a sum signal [S2C+2d] of the main microwave signal [S2c] at a specific level and the distortion signal [Sd], 20 denotes the an output-end hybrid for inputting one of the two microwave signals [S1c] output from the phase shifter [11] and the output [2Sc+Sd] from the distortion generator [21] to the input terminals [t1, t2], performing reverse-phase synthesis, outputting the resulting output signals [Sout] from output terminal [t3], performing same-phase synthesis, and outputting microwave signals [Sc] from the end terminal [t4], 22 denotes a termination circulator connected to the end terminal [t4] of the output-end hybrid [20], 30 denotes a control signal generator for generating control signals C based on the level of the microwaves [Sc] synthesized with the same phase at the end terminal [t4] of the output-end hybrid [20], and 100 denotes the high-voltage amplifier inputting the output [Sout] from the distortion compensation device of the present invention to compensate for the generated distortion.

[12] The distortion compensation device of the present invention is configured so that the variable phase shifter [11] and the variable attenuator [12] are controlled by the control signals C generated by the control signal generator [30], the variable phase shifter [11] shifts the phase of the split microwave signals [S1] so the output level of the microwave signals [Sc] at the end terminal [t3] of the output-end hybrid [20] is maximum, and the variable attenuator [12] changes the output level of the variable phase shifter [11]. /10

(Operation)

[13] The input-end hybrid [10] inputs microwave signals [Sin] with a plurality of modulated carrier waves, splits them into two split microwave signals [S1, S2] with a phase shift of 90° with respect to each other but the same level, and outputs the first split microwave signals [S1] to the variable phase shifter [11] and the second split microwave signals [S2] to the distortion generator [21].

[14] The phase shifter [11] uses the control signals C generated by the control signal generator [30] to shift the phase of the first split microwave signals [S1] in the output from the input-end hybrid [10], and outputs the first split microwave signals [S1c] with no error ε from the correct 90° phase shift with respect to the main microwave signals [S2c] outputted from the second distortion generator [21] via the variable attenuator [12] to the input terminal [t1] on the output-end hybrid [20].

[15] The distortion generator [21] inputs the second split microwave signals [S2] in the output of the input-end hybrid [10], performs non-linear amplification, generates microwave distortion signals [Sd], combines them with the main microwave signals [S2c], and outputs the sum [S2c+Sd] of the main microwave signals [S2c] and the microwave distortion signals [Sd] to the second input terminal [t2] of the output-end hybrid [20].

[16] The output-end hybrid [20] inputs the microwave signals [S1c] sent from the first variable phase shifter [11] via the variable attenuator [12] and the microwave distortion signals [S2c+2d] from the second distortion generator [11] to the input terminals [t1, t2], the two microwave signal inputs from the output terminal [t3] are reverse-phase synthesized, and the output signals with a discrepancy [Sout] are outputted as the output from the distortion compensation device of the present invention. At the same time, the output-end hybrid [20] performs same-phase synthesis on the main microwave signals [S1c, S2c] from the end terminal [t4], outputs the resulting microwave signals [Sc], and sends them to the control signal generator [30].

[17] If the two microwave main signals [S1c, S2c] inputted from the end terminal [t4] of the output-end hybrid [20] are at the correct 90° phase difference, the microwave signals [Sc] is at the maximum level. Otherwise, they are at a level reduced proportional to the phase error ε outputted to the end terminal [t4]. These signals are detected by the control signal generator [30], the

control signals C are generated based on the detected level, and these control signals C are supplied to the variable phase shifter [11] and the variable attenuator [12].

[18] If the phase shifter [11] maintains the correct 90° phase shift between the first microwave signals [S1c] and the second main microwave signals [S2c] inputted to the output-end hybrid [20], the reverse-phase synthesized output signals [Sout] from the output terminal [t3] are microwave signals consisting mainly of distortion signals [Sd]. If there is a level difference between the main signals [S1c] and the main signals [S2c], the output level is changed only by the difference.

[19] Thus, the variable attenuator [12] changes the output level of the variable phase shifter [11] using control signals C corresponding to the detected level, and the first microwave signals [S1c] and second main microwave signals [S2c] outputted from the distortion generator [21] are sent at an equal level to the first input terminal [t1] on the output-end hybrid [20].

[20] Because the levels of the inputted main signals [S1c] and main signals [S2c] are equal, there is no change in the level of the output signals [Sout] from the output terminal [t3] of the output-end hybrid [20]. Because the output signals [Sout] are outputted at a constant level, the problem is solved.

(Working Examples) /11

[21] FIG 2 is a block diagram of the distortion compensation device in the working example of the present invention. FIG 3 is a vector diagram used to explain the operation of the working example.

[22] In the FIG 2 block diagram, the input-end hybrid [10] is a split-line such as a micro strip line perpendicular hybrid, and the input terminal [t2] terminates with a dummy resistance [R1]. The microwave input signals [Sin] are, for example, quatrature amplitude modulated (QAM) microwave signals with multiple carrier frequency signals (1) inputted to the input terminal [t1]. Two split signals [S1, S2] (3) with a phase shift of 90° with respect to each other but at the same level are outputted from the output terminals [t3, 54], and the first split signals [S1] are outputted to the variable phase shifter [11], and the second split signals [S2] are outputted to the distortion generator [21].

[23] The variable phase shifter [11] comprises a fixed step phase shifter [111] and a variable step phase shifter [112]. It is a digital phase shifter shifting the phase of the inputted signals by a fixed amount. The fixed step phase shifter [111] shifts the phase by a predetermined amount and the variable step phase shifter [112] has a switch operated by the control signals C from the control signal generator [30] for switching to fixed phase steps. The phase of the first split signals [S1] outputted from the input-end hybrid [10] are shifted so the microwave signals [S1c] outputted to the variable attenuator [12] maintain the correct 90° phase difference with

respect to the second main signals [S2c] outputted from the distortion generator [21] without any phase error ε.

[24] The variable attenuator [12] comprises a variable resistance attenuator, and the level of the microwave signals outputted from the first variable phase shifter [11] is controlled by the control signals C from the same control signal generator [30] so the first microwave signals [S1c] (3) inputted to the input terminal [t1] on the output-end hybrid [20] have a level equal to the second main signals [S2c] outputted from the distortion generator [21].

[25] The distortion generator [21], for example, can be a microwave amplifier consisting of GaAs FET elements and micro strip lines. The direct current bias is selected for non-linear amplification, the second microwave split signals [S2] outputted from the input-end hybrid [10] are inputted, non-linear amplification is performed and, as the main signals [S2] are amplified and outputted, third-order and fifth-order distortion signals [Sd] are generated by intermodulation and combined with them. The second microwave signals (5) consisting of the sum [S2c+Sd] of the main signals [S2c] and distortion signals [Sd] at a given level are then inputted to the input terminal [t2] on the output-end hybrid [20].

[26] The output-end hybrid [20] is a split-line perpendicular hybrid much like the input-end hybrid [10] in which reverse-phase synthesis is performed on the microwave signals inputted to the input terminal [t1] and the input terminal [t2] for output signals [Sout] outputted from the output terminal [t3], and in which same-phase

synthesis is performed on the microwave signals inputted to the input terminal [t1] and the input terminal [t2] for output signals [Sc] outputted from the end terminal [t4]. The end terminal [t4] is terminated by a termination circulator [22] consisting of a Y-shaped circulator [221] terminated on one end by dummy resistance [222].

[27] The output-end hybrid [20] outputs the first microwave signals [S1c] from the variable attenuator [12] (3) and the second microwave distortion signals [S2c+Sd] (5) from the distortion generator [11] to the input terminals [t1, t2], performs the reverse-phase synthesis shown by vector A in FIG 3 at the output terminal [t3], and outputs output signals [Sout] (6).

[28] If the phase shift between the microwave signals [S1c] from the variable attenuator [12] (3) and the microwave main signals [S2c] from the distortion generator [11] (5) is the correct 90°, reverse-phase synthesis is performed on the main microwave signals [S1c, S2c] at output terminal [t3] as shown in FIG 3B, which cancel each other out. Only the distortion signal component [Sd] (4) generated by the distortion generator [21] in constant level microwave output signals [Sout] (6) are outputted as the output of the distortion compensation device in the working example of the present invention. At the same time, as shown in FIG 3C, same-phase synthesis is performed on the first microwave main signals [S2c] (3) and the second microwave (5) main signals [S2c], and microwave signals [Sc] (7) are outputted. If the phase difference is the correct 90°, as shown in FIG 3D, the maximum level microwave signals [Sc] (7) are sent from terminal end

[t4] to the control signal generator [30] via the termination circulator [22].

[29] The control signal generator [30] comprises a detector /12 [31] and a pulse generator [32]. The detector [31] detects microwave signals [Sc] outputted from the end terminal [t4] of the output-end hybrid [20] via the circulator [22], the pulse generator [32] generates control pulses C proportional to the detection level of the detector [31], and sets the variable phase shifter [11] and the variable attenuator [12] so the output level of the detector [31] is the maximum level.

[30] The variable phase shifter [11] is operated by the control pulses C outputted from the control signal generator [30] and, as explained above, it shift the phase of the first split signals [S1] from the output terminal [t3] on the input-end hybrid [10] so that the phase shift between the first microwave main signals [S1c] and the second microwave main signals [S2c] inputted to the input terminals [t1, t2] on the output-end hybrid [20] is the correct 90° without any phase error ε.

[31] The variable attenuator [12] is operated by the same control pulses C, and raises or lowers the microwave signals outputted from the variable phase shifter [11] so the amount of attenuation decreases when the output level of the detector [31] in the control signal generator [30] is high, and the output level of the detector [31] tends towards the maximum level.

[32] In other words, as shown in FIG 3E, the vector OA showing the output of the variable phase shifter [11] decreases from external vector AB, and if vector OB showing the output from the output terminal [t3] of the output-end hybrid [20] is not like vector OB' showing the output from the output terminal [t4], the amplitude of vector OA and the amplitude of vector OB are not equal. If, in this situation, the variable attenuator [12] is operated so the amplitude of the vector OA increases by AA' (=BC), vector OB becomes vector OA, and the amplitude of vector OA becomes equal. At this time, vector OB' showing the output from output terminal [t4] increases and becomes vector OC'. At this time, the variable attenuator [12] is operated to increase vector OB', and vector OB becomes vector OC, which is equal in size to vector OA.

[33] In other words, by operating the variable attenuator [12], the first main microwave signals [S1c] inputted to the output-end hybrid [20] has a level equal to the second main microwave signals [S2c] outputted from the distortion generator [21].

[34] Because the output-end hybrid [20] maintains the correct 90° phase difference and inputs the first main microwave signals [S1c] and second main microwave signals [S2c] at equal levels, the main signals [S1c, S2c] at the reverse-phase output terminal [t3] undergo reverse-phase synthesis and are cancelled out, leaving only the distortion signal component [Sd] outputted as the output signals [Sout] at a constant level.

[35] As explained above, the distortion compensation device in the working example of the present invention in FIG 2 maintains the phase difference between the first main microwave signals [S1c] and second main microwave signals [S2c] inputted to the output-end hybrid [20] at the correct 90° through the operation of the variable phase shifter [11]. However, because the levels of the main signals [S1c, S2c] are not coordinated, the difference in level between the main signals [S1c, S2c] at the output terminal [t3] of the output-end hybrid [20] changes the level of the output signals [Sout]. To solve this problem, the difference is eliminated by the variable attenuator [12] controlled independently and simultaneously by the control pulses C so the output signals [Sout] are outputted at a constant level. As a result, the output signals [Sout] from the distortion compensation device of the present invention are inputted to the high-power amplifier at a constant level, and the distortion is compensated for without any problem.

(Effect of the Invention)

[36] As explained above, the present invention automatically optimizes the phase of the variable phase shifter and the level of the variable attenuator in the output of the distortion compensation device to suppress leakage of microwave input signals directly causing unnecessary and harmful distortion signals. Because the distortion compensation device realizes a constant output level for the required distortion signals without fluctuation, the input of the output from the distortion compensation device of the present

invention to the high-energy amplifier has the effect of being able to compensate for any distortion within a wide range.

4. Brief Explanation of the Drawings

FIG 1 is a schematic of a distortion compensation device of the present invention.

FIG 2 is a block diagram of the distortion compensation device in the working example of the present invention.

FIG 3 is a vector diagram used to explain the operation of the working example. /13

FIG 4 is a block diagram of a distortion compensation device of the prior art.

In the figures,

10 denotes an input-end hybrid, 20 denotes an output-end hybrid, 11 denotes a variable phase shifter, 12 denotes a variable attenuator, 21 denotes a distortion generator, 22 denotes a termination circulator, 30 denotes a control signal generator, 31 denotes a detector, 32 denotes a pulse generator, and 100 denotes a high-power amplifier for compensation

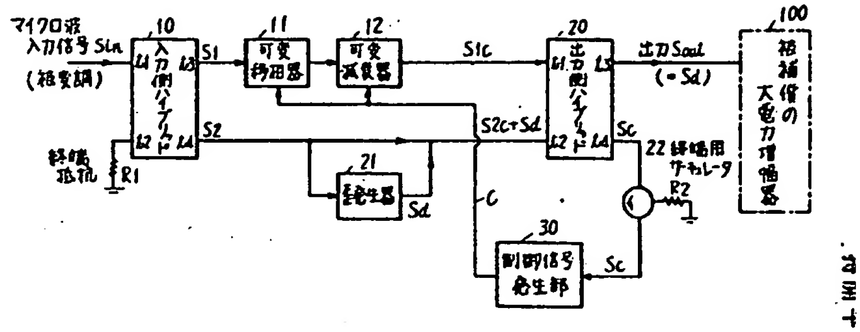

Figure 1

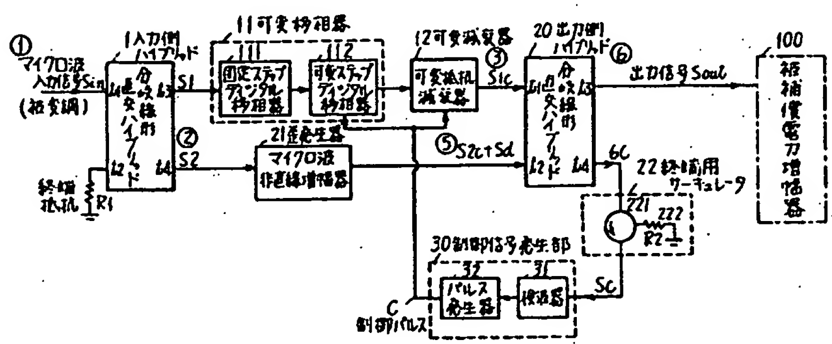

Figure 2

FIG 1: A schematic of a distortion compensation device of the present invention.

microwave input signals Sin (modulated)
terminal resistance R1
10 ... input-end hybrid
11 ... variable phase shifter
12 ... variable attenuator
20 ... output-end hybrid
output Sout (= Sd)
21 ... distortion generator
22 ... termination circulator
30 ... control signal generator
100 ... high-power amplifier for compensation

FIG 2: A block diagram of the distortion compensation device in the working example of the present invention.

microwave input signals Sin (modulated)
terminal resistance R1
10 ... input-end hybrid
11 ... variable phase shifter
111 ... fixed step digital phase shifter
112 ... variable step digital phase shifter
12 ... variable attenuator
20 ... output-end hybrid (split line perpendicular hybrid)
output signals Sout
21 ... distortion generator
non-linear microwave amplifier
22 ... termination circulator
30 ... control signal generator
control pulse C
31 ... detector
32 ... pulse generator
100 ... high-power amplifier for compensation

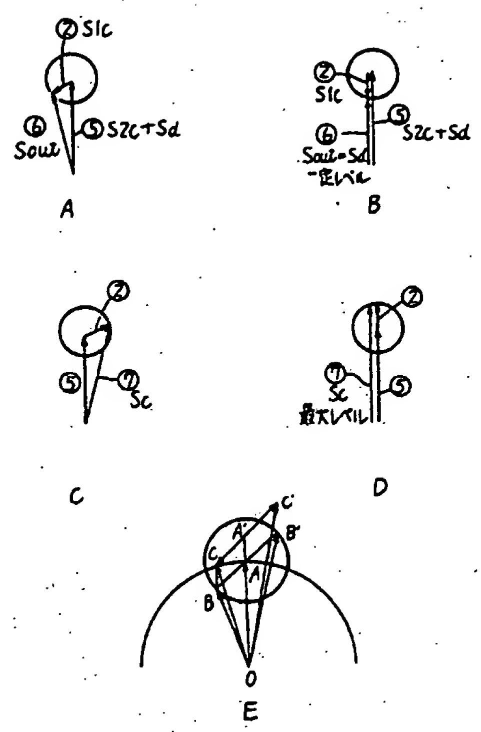

Figure 3

FIG 3: A vector diagram used to explain the operation of the working example.

B ... set level
C ... maximum level

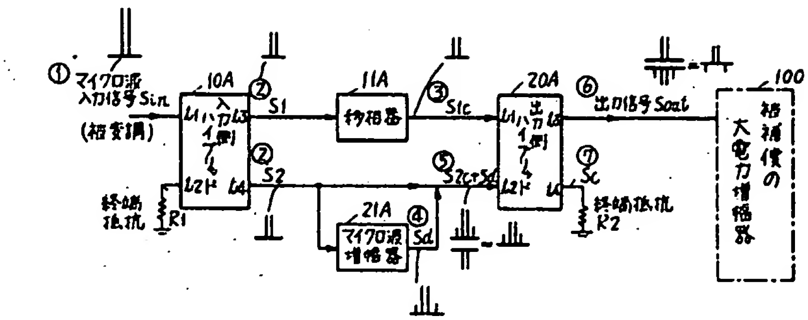

FIG 4: A block diagram of a distortion compensation device of the prior art.

microwave input signals Sin (modulated)
terminal resistance R1
10A ... input-end hybrid
11A ... variable phase shifter
20A ... output-end hybrid
output signal Sout
terminal resistance R2
21A ... microwave amplifier
100 ... high-power amplifier for compensation